

This research effort includes: 1) the development of new instrumentation to permit advanced measurements in the mid-infrared (2.5-25.0 μm) region of the spectrum; 2) the development of a spectral library of well-characterized mineral and rock specimens for interpretation of remote sensing data; and 3) cooperative measurements of the spectral signatures of analogues of materials that may be present on the surfaces of asteroids, planets or their moons.

New Instrumentation: Although bidirectional reflectance data in the 3-5 μm region of the spectrum can be used directly to predict the spectral behavior of a low temperature (less than 5C⁰) remotely sensed surface, emittance begins to dominate over reflectance at higher temperatures or longer wavelengths. Then, directional spectral emittance (i.e. in the direction of the observer) dominates. In order to predict the spectral behavior of remotely sensed surfaces under these conditions, it is necessary to measure directional hemispherical reflectance (Nicodemus, 1965).

A close approximation of directional hemispherical reflectance can be determined with an integrating sphere. The inside of the sphere must, however, be coated with a diffusely reflecting gold surface in order to function properly in the mid-infrared. We have contracted for the construction of such a sphere, which is to be delivered in November and will undergo its first tests in December, 1986. This sphere will provide the first spectral reflectance data of minerals and rocks from which directional spectral emittance can be confidently predicted.

More detailed, though much more time-consuming, measurements of directional reflectance can be made with a bidirectional reflectance device with adjustable angles of incidence and reflectance. Such a device is currently being designed at Goddard Space Flight Center and is due for completion in April, 1987. This device should make possible confirmation that the spectral contrast of a reflectance measurement at zero phase angle will be unaffected by particle size, as predicted by Salisbury and Eastes (1985). If so, reflectance measurements using lasers from orbiting spacecraft will avoid the ambiguities inherent in measurements of the spectral emittance of materials of different particle sizes.

Spectral Library: A library of mineral spectra has been started using a fixed angle bidirectional reflectance attachment. Relatively pure minerals, generally obtained from the Smithsonian collection, were crushed and further purified by hand picking. They were then checked for purity and further characterized by petrographic microscope (L. Walter), X-ray diffraction (N. Vergo), and electron microprobe (L. Walter) techniques. Thus, all samples studied have high purity so as to avoid spectral anomalies, and have been well characterized both mineralogically and chemically.

So far, more than 100 mineral samples have been processed and approximately 87 selected for spectral signature measurements (J. Salisbury). For each sample, the reflectance spectrum of the solid material is recorded, preferably in different crystallographic orientations, and then reflectance spectra are obtained of 74-250 μm and 0-74 μm size ranges. Finally, a small portion of the 0-74 μm size range is ground to less than 2 μm and incorporated into a KBr pellet for a transmittance measurement.

The procedure described above yields a variety of spectral data appropriate for different observational conditions or for surfaces of different particle size ranges. One important result of these early measurements is to show that quite different spectral features must be measured in remote sensing of coarse and fine particulate surfaces. This is illustrated in Figures 1 and 2, which show reflectance spectra of olivine (11% forsterite) from 4600 cm^{-1} ($2.17\text{ }\mu\text{m}$) to 400 cm^{-1} ($25.0\text{ }\mu\text{m}$). In both spectra a less than $30\text{ }\mu\text{m}$ particle size range was used, but firmly packed in Figure 1 and sifted in Figure 2. Packing increases the effective particle size (Salisbury & Eastes, 1985), resulting in prominent reflectance peaks (reststrahlen bands) associated with the molecular vibration bands. Of special interest is the double peak due to the Si-O stretching vibration between 1000 cm^{-1} ($10\text{ }\mu\text{m}$) and 800 cm^{-1} ($12.5\text{ }\mu\text{m}$), because it is in the region of terrestrial atmospheric transparency. A reflectance spectrum of the same olivine sample sifted into the sample holder (Fig. 2) shows that this reststrahlen band has greatly decreased in spectral contrast due to the increased porosity (Salisbury & Eastes, 1985). It also shows a completely new spectral feature in the form of the broad peak centered about 700 cm^{-1} ($14\text{ }\mu\text{m}$). This peak is not directly related to the molecular vibration bands, but is instead associated with transparent behavior due to the low absorption coefficient between the stretching and bending vibrations at longer wavelength (Salisbury et al, 1986). We have been able to show, however, that the wavelength of this transparency peak is just as diagnostic of composition as are those of the reststrahlen bands. Thus, compositional remote sensing of a fine particulate surface using the transparency peak can be accomplished despite the loss of spectral contrast of the reststrahlen bands that make them difficult to detect (Salisbury and King, in preparation).

Cooperative Efforts: Several colleagues have an interest in the mid-infrared spectral signatures of meteorites, proton bombarded frost residues and even more exotic materials that may be analogues of materials present on the surfaces of asteroids, planets or their moons. We encourage the use of our facility to obtain spectra of these analogues for comparison with telescopic spectral data. To date, we have had such cooperative efforts with Dale Cruikshank of the Un. of Hawaii; Tom Jones, a graduate student of John Lewis' at the Lunar and Planetary Laboratory of the Un. of Arizona, Tucson; and Trude King of the University of Hawaii and the USGS, Denver.

References

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- Salisbury, J.W. and Eastes, J.W., 1985, The effect of particle size and porosity on spectral contrast in the mid-infrared: *Icarus*, v 64, p. 586-588.
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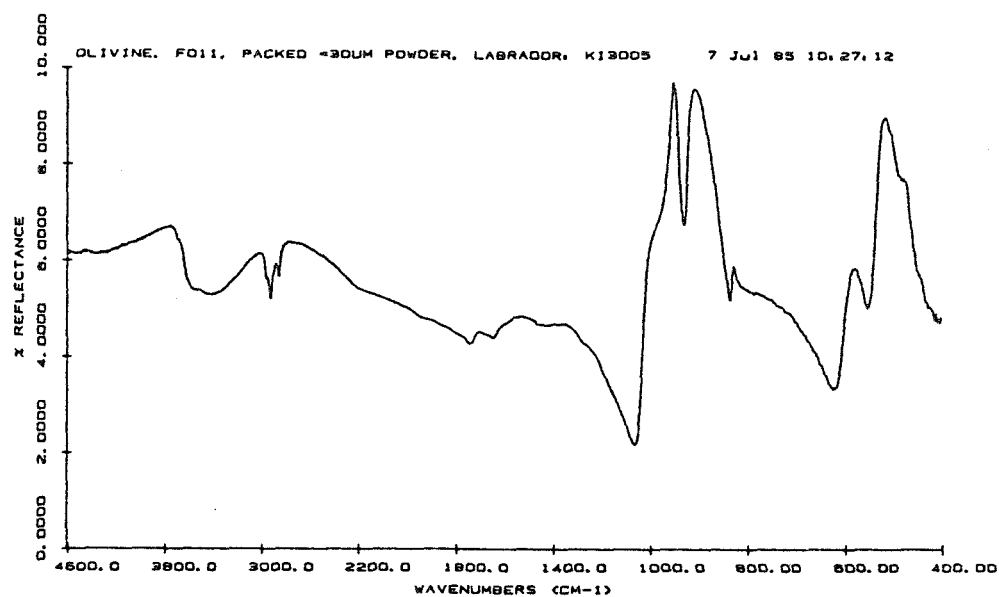


Figure 1. Bidirectional reflectance spectrum of packed olivine powder (less than 30 um).

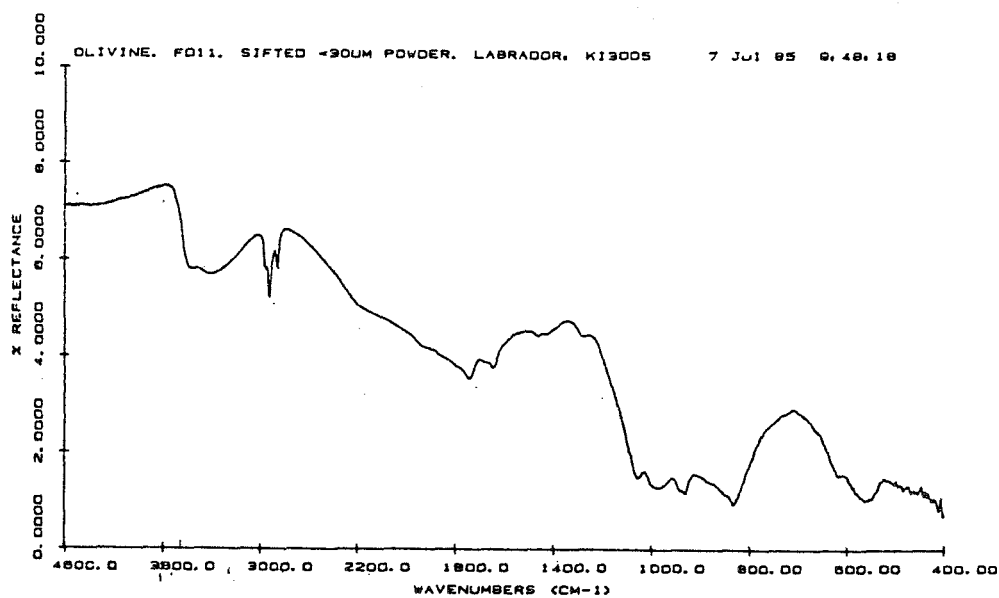


Figure 2. Bidirectional reflectance spectrum of sifted olivine powder (less than 30 um).